FINAL PROJECT REPORT

SCALES OF DECISION MAKING AND THE CARBON CYCLE

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Project Summary:

Processes on land are responsible for uptake and release of a significant portion of the carbon exchanged with the atmosphere each year. Converting forests to agricultural land, for example, adds carbon to the atmosphere above what would be exchanged through biospheric processes. Conversely, some processes such as forest regrowth and the extension of woody shrubland are likely taking up some of the anthropogenic carbon released, and are a "sink" for carbon. Some land management techniques have been found to increase carbon storage and have been included in voluntary carbon trading markets and policy frameworks being considered. While a significant amount of research effort has been devoted to measuring carbon exchange and characterizing carbon sinks from a biophysical perspective, less effort has been devoted to characterizing the decision making processes that control land use processes on land as they pertain to carbon.

Most decisions about land use are made at the local level, but governed by influences at a wide variety of scales, including local zoning policy, county and state tax code, market dynamics for commodities, cultural norms, national agricultural and even energy and environmental policy. While biophysical research may be able to indicate a significant potential for additional carbon storage based on vegetation types and land management practices, this potential can only be realized if decision making is aligned with priorities for storing carbon. It is therefore important to understand land use decision making drivers and the scales at which influences on decision making operate in order to understand the true potential for carbon storage on land, and the barriers and challenges for policy in this area.

This research project examined the characteristics of the land ownership pattern and its relationship to carbon stores and fluxes, the influences on decision making for public and private sector land managers, how carbon currently factors into decision making,

and the sources from where decision makers obtain information. The last issue is relevant for other research efforts, including the North American Carbon Program, which is interested in decision support for carbon management and decision making but which does not yet have strong evidence for what and how information is needed at different scales of decision making. We focus here on land use decision making in two states, Colorado and Pennsylvania, which have contrasting land use histories, vegetation types and ownership patterns. We used GIS, interviews with decision makers, and policy documents to investigate the land use decision making landscape for carbon at different scales.

Introduction

Land use is a key process that affects the global distribution of carbon through agriculture and forestry activities. Most climate change policies, including Colorado's Climate Change Action Plan (CCAP 2007) and the recently proposed Waxman-Markey bill (H.R. 2454), promote land management as a means to ameliorate the concentration of atmospheric carbon dioxide. The land use pattern and its attendant carbon impacts are a manifestation of a complex set of policy, economic, and cultural drivers that are channeled and expressed through individuals making decisions about land use. Methods to improve carbon sequestration through vegetation and soil management have been described as low cost, short-term means for mitigating a significant portion of future emissions (Kinsella 2002). However, estimates of the technical potential of carbon sequestration on land in different land cover types or under different management practices focus primarily on the private sector and are determined primarily by economic and/or crop models (Buyanovsky and Wagner 1998, Conant and Paustian 2002, Sperow et al 2003, Pacala and Socolow 2004, Antle et al 2007) when in fact other diverse and nonmonetary benefits often significantly influence land management decisions (Koontz 2001). Carbon research frequently does not take into account whether the decision maker will in fact pursue the necessary steps to maximize carbon storage on the land or address carbon sequestration potential on non-private lands.

A range of goals and influences drive land use decision makers (Lambin et al. 2001, Koontz 2001). To understand how decision makers might influence the outcome of carbon stock changes and fluxes on land, it is necessary to understand both the types of decision makers and what drives their decision making. In the United States, there is a complex range of decision makers determining the pattern of land use (Lubowski et al 2006) and attendant carbon storage (Dilling 2007). A significant portion of land nationwide (37%) is owned and managed by the public sector, either through federal agencies or through states and local governments. The majority of land is owned by private individuals and corporations (60%) and a small fraction (1%) are tribal lands (Lubowski et al 2006). In reality, all decision makers have choices about what to do with the land they manage, but the stewardship priorities that influence those choices differ

between public and private land managers and among different land management sectors and agencies. Land management priorities, in other words, are a key factor in whether or not the technical potential for additional carbon storage on land will be realized. While many policies aim to enhance carbon sinks, this study analyses the land tenure and management practices for existing carbon stocks and fluxes as a first step in characterizing what we term the carbon stewardship landscape. If policies come into effect that target particular land cover types in order to enhance sequestration, land tenure and management patterns will be critical to understanding how technical carbon sequestration might translate into actual carbon sequestration in the vegetation and soils.

General Methods

Our study presents here a first-order look at how terrestrial carbon stocks and fluxes are currently distributed by land ownership category and considers what this might mean for additional carbon sequestration potential. Because they present a microcosm of the diversity of land ownership types in the U.S., we chose to focus on Colorado and Pennsylvania as our initial test cases for different parts of the project.

We evaluated the carbon stewardship landscape in Colorado by examining Colorado's land tenure and land cover patterns, calculating estimates of carbon flux and stock by land ownership category and considering the implications of understanding land stewardship for assessing carbon sequestration potential on land. We have completed a first look at how carbon storage maps on to vegetation cover, and by proxy, carbon stocks and fluxes using GIS analysis. We created a geographic information system (GIS) to analyze existing spatial vegetation and stewardship data in Colorado and to combine vegetation data with published estimates of vegetation carbon stock and flux in order to evaluate the state's carbon stewardship. We used Colorado Ownership, Management and Protection (COMaP) (Theobald et al 2008) and LANDFIRE Existing Vegetation Type data (USGS 2008) in our GIS. We conducted a literature review and compiled carbon stock and flux estimates from published studies and reports as well as from an unpublished report by Conant et al (2007). Although we sought measurements specific to Colorado, we had to rely on calculations from the western and contiguous U.S. when Colorado-specific data were not available. Estimates that evaluated both vegetation and soil carbon were preferred, but we also considered soil carbon measurements when combined vegetation and soil carbon values were not available. We converted all published carbon data into megagrams of carbon (Mg C) and all area measurements into hectares (ha). Negative flux values represent carbon sequestered in vegetation and soils (sinks) whereas positive values correspond to carbon released to the atmosphere (sources) (Failey and Dilling, submitted, table 1).

Table 1: Fluxes and stocks of carbon in Colorado (from Failey and Dilling, submitted)

Land cover type [**Area** (Mha)]	Flux range (Mg C $ha^{-1} yr^{-1}$)	Stock range (Mg C ha^{-1})
Water/Snow/Ice [**0.20**]	—	—
Riparian/Wetland [**0.53**]	0.61[a] to -0.24[b]	198.60[a] to 1540.49[a]
Barren/Sparsely vegetated [**0.56**]	—	—
Developed [**0.70**]	-0.31[a] to -3.83[c]	6.32[d] to 47.58[c]
Agriculture [**4.05**]	0[a] to -0.22[e]	16.62[c] to 95.10[a]
Forest [**8.43**]	-0.57[e] to -1.21[e]	102.38[f] to 224.83[a]
Grassland/Shrubland [**12.50**]	0.03[d] to -0.07[d]	47.77[c] to 107.44[a]

[a] CCSP 2007
[b] Chimmer & Cooper 2003
[c] Kaye *et al* 2005
[d] Conant *et al* 2007
[e] Pacala *et al* 2001
[f] Goodale *et al* 2006

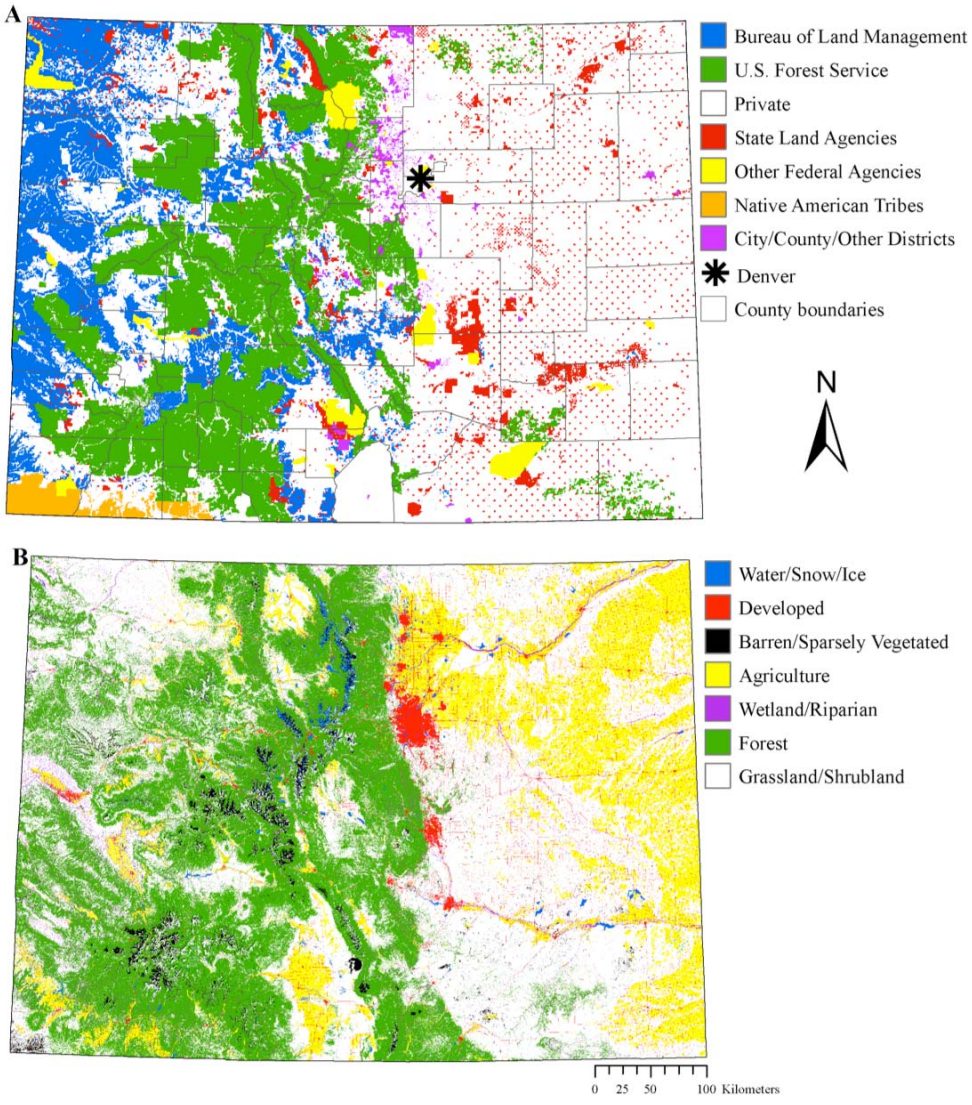
We also looked in detail at land use decision making in Pennsylvania and Colorado through case studies. Both Pennsylvania and Colorado have been exploring how to better manage lands within the states for carbon sequestration. In Pennsylvania, we conducted research examining what types and scale of information would be usable to state public lands managers through conjoint analysis. In Colorado, we interviewed over 30 land managers in both public and private sectors to understand the influences and priorities for decision making at different scales. In Colorado we interviewed 15 federal land managers, 12 private owners (ranchers and farmers), and a few state and tribal land managers.

Results

In Pennsylvania, we found that state land use managers in forestry were fairly pleased with the information they were using to manage forests, although it was unclear how needs would change if carbon sequestration became a top policy priority. Policy managers were generally pleased with larger scale information on the impacts of climate change on forests, and required smaller scale information for actually making management decisions (Vanderbrink 2008).

Colorado is a western state measuring approximately 26.96 million hectares (Mha) in size and has a stewardship pattern similar to the rest of the U.S. with majority ownership held by the private sector and federal government agencies having the second largest stake in land holdings (Lubowski et al 2006). The three institutions with

the largest stake in Colorado's land management are the private sector (57%), the USFS (22%) and the BLM (13%). The other land stewards in Colorado are the State (5%), other federal government agencies (i.e. Department of Energy and National Parks Service) (2%), and cities, counties and other districts (1%); Native American tribes manage 1% of Colorado's land in the southwestern corner of the state (figure 1a). Similarly, Colorado's vegetation cover pattern parallels that of the U.S. as a whole (Lubowski et al 2006, Lal et al 2003). Grassland/shrubland is the primary land cover (46%) followed by forests (31%) and agriculture (15%); developed land (3%), barren/sparsely vegetated (2%), riparian/wetlands (2%), and water (1%) cover the remainder of Colorado (figure 1b).



The stewardship flux and stock range estimates positively correlate with land area; the larger the land area the greater the flux and stock managed by the area's steward (table 2). The private sector manages the greatest land area in the state and the largest current carbon flux (-1.02 Tg C yr^{-1} to -6.48 Tg C yr^{-1}) and stock (733 Tg C to 2150 Tg C). The USFS carbon flux (-2.31 Tg C yr^{-1} to -5.33 Tg C yr^{-1}) is a close second to the private sector and the agency manages the second largest carbon stock (512 Tg C to 1296 Tg C) in Colorado. The BLM and the State are the third and fourth largest carbon flux and stock managers, respectively (Table 2).

Table 2. Colorado carbon stewardship range of estimates of flux and stock

Landowner	Area (Mha)	Flux range (Tg C yr^{-1})	Stock range (Tg C)
Private	15.37	-1.02 to -6.48	733 to 2150
USFS	5.84	-2.31 to -5.33	512 to 1296
BLM	3.37	-0.740 to -1.97	250 to 645
State	1.31	-0.07 to -0.39	71.8 to 187
Other Federal	0.54	-0.079 to -0.26	32.7 to 88.1
Native American	0.31	-0.08 to -0.21	22.3 to 54.6
City/County/Other Districts	0.23	-0.03 to -0.15	13.7 to 43.3

It is clear that factors at multiple scales influence decision making for both the public and private sector in Colorado. The private sector is influenced by a number of factors. Of course economic viability was a primary concern, but other factors such as ease of record keeping requirements, values about the land, water rights and availability, as well as access to various incentive programs for land conservation were also important drivers. Decision making in the public sector is governed by plans and processes subject by law to public input and scrutiny. The National Environmental Protection Act (NEPA) is the primary mechanism by which the public provides input into how the Bureau of Land Management (BLM), Forest Service (FS) and other federal agencies make decisions. Each field office generally has a 15 year plan which sets broad guidance for the proportion of land reserved for each type of activity, such as recreation, grazing, oil and gas leasing, timber harvest, etc.

Both the Department of Interior and US Forest Service have issued mandates to consider climate change, but how this translates into decisions on the ground at the field office scale is currently being worked through. Many of those interviewed expressed that they were aware of the need to figure out how to manage for climate change, but were challenged by how the available climate change information related to the scale at

which decisions were being made (Dilling and Failey in preparation). The "accumulated impact" of decisions on climate change as a whole was one issue in particular that was mentioned and for which there was no clear way to resolve with the legal structures and currently available science.

Because of the uncertainty for how to deal with climate in the decision making framework, and because of the immediacy of many of the existing mandates for decision making, climate change and carbon management is on the radar screen for many of these agencies, but does not currently drive decision making compared to other uses and events such as the pine beetle outbreak or considering new recreational needs in Colorado.

A common thread that emerged from the research in both Colorado and Pennsylvania was the fact that carbon was not yet a deciding factor in making management decisions in either state. Other factors such as environmental concerns, economic viability, existing practices and limitations, and decision autonomy dominated the responses for why decision makers might not yet be valuing carbon sequestration as a primary goal of land management. This may change of course as carbon storage becomes a more important issue in the future.

Conclusions

Previous studies calculated the potential carbon sequestered on lands that adopt recommended management practices (RMPs) (Lal et al 2003, Heath et al 2003, Conant et al 2001), but seemingly do not account for the entire carbon stewardship landscape, which greatly impacts the ability for carbon management practices to be employed. Carbon is currently a secondary concern at best among the demands for land services. Studies are still inconclusive but some evidence indicates that primary needs (i.e. reducing erosion, mitigating for fire, and producing lumber) can be compatible with carbon management practices (CCSP 2007, Hurteau et al. 2008, North et al. 2009). The U.S. Federal Government has yet to issue mandatory guidance to manage for carbon, and public land managers frequently have more pressing demands such as tourism and resource extraction. The economics of various options as well as external influences such as energy policy (e.g. incentives for biofuel production) also strongly determine which practices might be implemented whether on private or public lands. Moreover, many private land managers are unwilling to take the risk and change their management practice to implement voluntary carbon management practices given the current economic incentives and contract design, and the uncertain impacts on agricultural production (Dilling and Failey in prep).

Although quantitative estimates of the impact of land-use change and different management practices are highly uncertain, carbon accounting may become a critical carbon management component, increasing the need for improved data (CCSP 2007).

Applying estimates of fluxes and stocks provides a first-order look at the carbon landscape, but a more realistic estimate of potential additional carbon storage can be obtained by including ownership categories. Terrestrial carbon sequestration practices will need to be adopted extensively in order to have any significant impact in reducing atmospheric carbon dioxide (Pacala and Socolow 2004) and any policies to incentivize sequestration must consider the decision making and stewardship landscape.

A first look at the carbon stewardship landscape reveals a complicated set of ownership patterns and vegetation types. Coupled with diverse incentives not yet focused on carbon considerations, this landscape represents a challenge for both research and policy focused on enhancing carbon sequestration on land. For private land owners, in addition to weak incentives, not all land types or counties are yet eligible for the existing voluntary market options (CCX 2009). The potential role of public lands in sequestering additional carbon through management has been recognized, but processes and procedures are not yet implemented on the ground to make carbon storage a priority. Moreover, the impact of the multiple competing uses for public lands on carbon storage is uncertain, and how these tradeoffs will be negotiated remains to be seen. Future efforts should consider the carbon stewardship landscape, including institutions, policies, and values, to obtain more realistic estimates and, ultimately, more effective policies for carbon sequestration.

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Informing Decision Making

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Kelly Vanderbrink, Master’s student at Penn State supported by this project, and Dr. Bill Easterling, Professor at Penn State, are both members of the Carbon Management Advisory Group of the State of Pennsylvania Department of Conservation and Natural Resources and have brought research to state officials and others. http://www.dcnr.state.pa.us/carbon/